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(54) Title: METHOD OF ETCHING CARBON-CONTAINING SILICON OXIDE FILMS

(57) Abstract: We have discovered a method for plasma etching a carbon-containing silicon oxide film which provides excellent etch profile control, a rapid etch rate of the carbon-containing silicon oxide film, and high selectivity for etching the carbon-containing silicon oxide film preferentially to an overlying photoresist masking material. Then the method of the invention is used, a higher carbon content in the carbon-containing silicon oxide film results in a faster etch rate, at least up to a carbon content of 20 atomic percent. In particular, the carbon-containing silicon oxide film results in a faster etch rate, at least up to a carbon content of 20 atomic percent. In particular, the carbon-containing silicon oxide film is plasma etched using a plasma generated from source gas comprising  $\text{NH}_3$  and  $\text{C}_4\text{F}_8$ . It is necessary to achieve the proper balance between the relative amounts of  $\text{NH}_3$  and  $\text{C}_4\text{F}_8$  in the plasma source gas in order to provide a balance between etch by/product polymer deposition and removal on various surfaces of the substrate being etched. The  $\text{NH}_3$  gas functions to "clean up" deposited polymer on the photoresist surface, on the etched surface, and on process chamber surfaces. The atomic ratio of carbon: nitrogen in the plasma source gas typically ranges from about 0.3:1 to about 3:1. We have found that  $\text{C}_2\text{F}_6$  and  $\text{C}_4\text{F}_8$  provide excellent etch rates during etching of carbon-containing silicon oxide films.

1            METHOD OF ETCHING CARBON-CONTAINING SILICON OXIDE FILMS

2  
3            **BACKGROUND OF THE INVENTION**

4            1. Field of the Invention

5            The present invention pertains to etching of carbon-containing silicon oxide films.

6            2. Brief Description of the Background Art

7            Low k dielectric materials are the trend for the next generation of dielectric materials  
8            used in semiconductor manufacture. The term "low k dielectric" typically refers to any  
9            material having a dielectric constant (k) value lower than that of silicon dioxide (k = 4.0).  
10           There are many different kinds of low k dielectric materials, including organic polymer-  
11           based materials, as well as silicon oxide-based materials which contain additives such as  
12           fluorine, carbon, and hydrogen.

13           Various methods for producing carbon-containing silicon oxide films are known in  
14           the art. U.S. Application Serial No. 09/021,788, of Yau et al., and German Patent No. DE  
15           19654737, of Itoh et al., for example, disclose methods for producing such films. In  
16           particular, the '788 application discloses a method for depositing a low dielectric constant  
17           film by reacting an organosilane compound (such as methyl silane,  $\text{CH}_3\text{SiH}_3$ ) with an  
18           oxidizing gas (such as  $\text{N}_2\text{O}$  or  $\text{O}_2$ ). During deposition of the film, methyl ( $\text{CH}_3$ ) groups bond  
19           to the silicon oxide structure. The presence of carbon in the film causes a reduction in the  
20           dielectric constant of the film.

21           Plasma etching of silicon oxide films is typically performed using a source gas  
22           containing a  $\text{C}_x\text{F}_y$  gas, such as  $\text{CF}_4$  or  $\text{C}_2\text{F}_6$ . The carbon and fluorine in the source gas are  
23           typically sufficient to provide an acceptable etch rate for the silicon oxide. However, for  
24           carbon-containing silicon oxide films, etching cannot proceed very far when  $\text{C}_x\text{F}_y$  is used as  
25           the sole etchant gas. The carbon in the film, together with the carbon and fluorine in the

1 plasma source gas, combine to produce undesirable long-chain carbon-fluorine polymers  
2 which deposit over surfaces of the semiconductor structure being etched, hampering the  
3 etching process. The long-chain carbon-fluorine polymers also contaminate surfaces within  
4 the process chamber.

5 Prior art solutions to this problem have included adding a source of oxygen to the  
6  $C_xF_y$  gas. The oxygen reacts with the carbon in the carbon-containing silicon oxide film,  
7 preventing undue polymer deposition and increasing the etch rate of the film. However,  
8 oxygen also attacks the overlying photoresist layer, which is typically used as a patterning  
9 mask for underlying feature (such as a contact via) etching. Therefore, although the  
10 presence of oxygen improves the etch rate of the carbon-containing silicon oxide film, the  
11 selectivity for etching the silicon oxide film in preference to an overlying photoresist layer  
12 is reduced.

13 It would be desirable to provide an effective method for etching carbon-containing  
14 silicon oxide films that would provide both an acceptable etch rate and acceptable selectivity  
15 for etching the silicon oxide film relative to an overlying photoresist layer.

## 16 SUMMARY OF THE INVENTION

17 We have discovered a method for plasma etching a carbon-containing silicon oxide  
18 film which comprises exposing the film to a plasma generated from a source gas comprising  
19  $NH_3$  and  $C_xF_y$ . The carbon-containing silicon oxide film generally comprises less than about  
20 20 atomic percent carbon; typically the carbon content ranges from about 8 to about 20  
21 atomic percent carbon; more typically, the carbon content ranges from about 8 to about 13  
22 atomic percent carbon. The carbon-containing silicon oxide film frequently contains  
23 hydrogen. When hydrogen is present, the hydrogen concentration is generally less than  
24 about 45 atomic percent of the overall film composition. Typically the hydrogen

1 concentration ranges from about 30 to about 45 atomic percent; more typically, the  
2 hydrogen content ranges from about 30 to about 40 atomic percent of the carbon-containing  
3 silicon oxide film.

4 Active fluorine species in the etchant plasma react with silicon in the carbon-  
5 containing silicon oxide film (substrate). Oxygen species generated from the carbon-  
6 containing silicon oxide film and hydrogen species from the plasma react with carbon. The  
7 method of the invention provides excellent etch rates, as well as superior etch selectivity for  
8 the carbon-containing silicon oxide layer in preference to an overlying photoresist masking  
9 material. It is our opinion, but not by way of limitation, that etch selectivity is improved  
10 because a layer of polymer (generated from the  $C_xF_y$  in the plasma source gas) is deposited  
11 upon the upper surface of the photoresist masking layer during the etching process. This  
12 layer of deposited polymer protects the photoresist from being consumed during the silicon  
13 oxide etching process. Simultaneously, the ammonia ( $NH_3$ ) gas portion of the plasma source  
14 gas functions to "clean up" deposited polymer on the photoresist surface, on the etched  
15 surface, and on the process chamber surfaces. It is necessary to achieve the proper balance  
16 between the  $C_xF_y$  and  $NH_3$  in the plasma source gas in order provide a balance between by-  
17 product polymer deposition and removal on various surfaces of the substrate being etched.  
18 Oxygen may be added to the plasma source gas to increase the etch rate of the carbon-  
19 containing silicon oxide, but this reduces the selectivity in favor of etching of the carbon-  
20 containing silicon oxide relative to the photoresist.

21 Carbon and nitrogen are typically present in the source gas in an atomic ratio within  
22 a range of about 1 : 0.3 to about 1 : 3 of carbon : nitrogen; preferably, within a range of  
23 about 1 : 0.7 to about 1 : 2.2 of carbon : nitrogen; and more preferably, within a range  
24 of about 1 : 1 to about 1 : 1.8.

25 The method of the invention comprises exposing the carbon-containing silicon oxide

1 film to a source gas comprising  $\text{NH}_3$  and  $\text{C}_x\text{F}_y$ , where x ranges from about 1 to about 6 and  
2 y ranges from about 4 to about 8. Typically, x = 2 to 4 and y = 4 to 8. In particular, we  
3 have found that  $\text{C}_2\text{F}_6$ ,  $\text{C}_4\text{F}_6$ ,  $\text{C}_4\text{F}_8$ , and  $\text{C}_3\text{F}_8$  provide excellent etch rates and etch selectivity.

4 Although less preferred, the plasma source gas may further include a non-reactive,  
5 diluent gas selected from the group consisting of argon, helium, xenon, krypton, and  
6 combinations thereof.

7 The method of the invention for etching carbon-containing silicon oxide films has  
8 provided etch rates of at least  $2.2\ \mu\text{m}$  per minute and etch selectivity relative to an overlying  
9 photoresist layer of up to about 25 : 1. This combination of rapid etch rate of the carbon-  
10 containing silicon oxide with high etch selectivity relative to the photoresist masking layer  
11 was unexpected. Also important is the clean process chamber surface after completion of  
12 etch.

#### 13 BRIEF DESCRIPTION OF THE DRAWINGS

14 Figure 1 shows an IPS<sup>TM</sup> etch process chamber 100 of the kind used during the  
15 generation of the data illustrated in Figure 2.

16 Figure 2 shows the effect of changes in  $\text{C}_4\text{F}_8$  and  $\text{NH}_3$  gas feed rates to the plasma  
17 on the profile taper of an etched contact via; the etch selectivity, in terms of preference for  
18 etching carbon-containing silicon oxide relative to photoresist masking material; the etch  
19 rate of photoresist masking material; and the etch rate of carbon-containing silicon oxide.

#### 20 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

21 Described in detail below is a method of etching a carbon-containing silicon oxide  
22 film. The method involves exposing the film to a plasma generated from a source gas  
23 comprising  $\text{NH}_3$  and  $\text{C}_x\text{F}_y$ .

1           As a preface to the detailed description, it should be noted that, as used in this  
2           specification and the appended claims, the singular forms "a", "an", and "the" include plural  
3           referents, unless the context clearly dictates otherwise.

#### 4           I.       AN APPARATUS FOR PRACTICING THE INVENTION

5           Figure 1 shows an example of an apparatus which can be used to practice the method  
6           of the invention, the Applied Materials IPS™ dielectric etch chamber (designated by  
7           reference numeral 100). The IPS™ chamber 100 includes two plasma power sources,  
8           provided by an outer coil 102 (frequency tuned at  $2.0 \pm 0.1$  MHz) and an inner coil 104  
9           (frequency tuned at  $2.3 \pm 0.1$  MHz). A substrate (not shown, but typically a silicon wafer)  
10          is held to a support platform, which is typically a ceramic electrostatic chuck 108. A bias  
11          voltage may be applied to substrate support platform 108 by means of bias power source 106  
12          (frequency tuned at  $1.7 \pm 0.2$  MHz). Plasma source gas is fed into the etch chamber from  
13          a location 110 which is beneath the substrate and moves toward the upper portion of etch  
14          chamber 100, where a plasma is generated. The method of the invention is preferably  
15          performed in an apparatus having separate power controls for the plasma source power and  
16          substrate bias power.

17          Although the above apparatus provides excellent results, it is expected that the  
18          method can also be carried out in other apparatus of various kinds known in the art,  
19          including, but not limited to, RF generated parallel plate; electron cyclotron resonance  
20          (ECR); high-density reflected electron, helicon wave, inductively coupled plasma(ICP) and  
21          transformer coupled plasma (TCP) apparatus. Examples of such processing apparatus are  
22          described in U.S. Patent Nos. 6,095,084; 6,077,384; 6,074,512; 6,071,372; 6,063,233;  
23          6,054,013; 6,036,878; 6,026,762; 6,020,686; 5,976,308; and 5,900,064, each of which is  
24          hereby incorporated by reference.

1 II. THE METHOD OF THE INVENTION FOR ETCHING  
2 A CARBON-CONTAINING SILICON OXIDE FILM

3 The present invention pertains to etching of carbon-containing silicon oxide films.  
4 Typically, the films consist of methyl ( $\text{CH}_3$ ) groups bonded to a silicon oxide structure.  
5 Carbon is generally present at less than about 30 atomic percent. Typically, the carbon  
6 content is within a range of about 8 to about 20 atomic percent; more typically, within the  
7 range of about 8 to about 13 atomic percent, of the silicon oxide film. The carbon content  
8 of the silicon oxide film is important because it affects both the general mechanical  
9 properties of the film and the conductivity of the film.

10 Hydrogen is also frequently present in the carbon-containing silicon oxide film.  
11 Generally, the hydrogen concentration is less than about 50 atomic percent. Typically, the  
12 hydrogen content is within a range of about 30 to about 45 atomic percent of the silicon  
13 oxide film.

14 The method of the invention comprises exposing the carbon-containing silicon oxide  
15 film to a plasma generated from a source gas comprising  $\text{NH}_3$  and  $\text{C}_x\text{F}_y$ . Carbon and  
16 nitrogen are typically present in the plasma source gas in an atomic ratio within the range  
17 of about 0.3 : 1 to about 3 : 1 of carbon : nitrogen; preferably, within the range of about 0.5  
18 : 1 to about 1.4 : 1 of carbon : nitrogen; most preferably, within the range of about 0.6 : 1  
19 to about 1 : 1 of carbon : nitrogen. With reference to the  $\text{C}_x\text{F}_y$  gas, x typically ranges from  
20 about 1 to about 6, and y typically ranges from about 4 to about 8. The  $\text{C}_x\text{F}_y$  gas is typically  
21 selected from the group consisting of  $\text{C}_2\text{F}_6$ ,  $\text{C}_3\text{F}_8$ ,  $\text{C}_4\text{F}_6$ ,  $\text{C}_4\text{F}_8$ ,  $\text{C}_5\text{F}_8$ , and combinations thereof.  
22 In particular, we have found that  $\text{C}_2\text{F}_6$  and  $\text{C}_4\text{F}_8$  provide excellent etch rates and etch  
23 selectivity.

24 The plasma source gas may further include oxygen in order to increase the etch rate  
25 of the carbon-containing silicon oxide film. However, oxygen should comprise no more  
26 than about 30 volume % of the source gas, and typically less than about 20 volume %, as the

presence of oxygen may compromise the selectivity for etching the carbon-containing silicon oxide film relative to an overlying photoresist layer.

Although less preferred, the plasma source gas may further include a non-reactive, diluent gas selected from the group consisting of argon, helium, xenon, krypton, and combinations thereof.

Typical process conditions for etching a carbon-containing silicon oxide film according to the method of the invention, when the power supply is controlled separately for the plasma source power and the substrate bias power, are presented in Table One, below.

In cases where there is only a single plasma source power, the "Inner (W)" source power value is simply "0 W".

Table One. Preferred Embodiment Process Conditions for Etching Carbon-containing Silicon Oxide Films

Process Parameter	Preferred Process Conditions	More Preferred Process Conditions	Most Preferred Process Conditions
NH <sub>3</sub> Flow Rate (sccm)	50 - 150	75 - 125	75 - 100
C <sub>x</sub> F <sub>y</sub> Flow Rate (sccm)	10 - 30	15 - 25	18 - 25
O <sub>2</sub> Flow Rate (sccm)	0 - 30	0 - 20	0 - 10
Ar Flow Rate (sccm)	0 - 1000	0 - 800	0 - 500
Plasma Source Power* - Outer (W)	800 - 2000	800 - 1600	1000 - 1600
Plasma Source Power* - Inner (W)	0 - 1000	0 - 600	0 - 500
Substrate Bias Power** (W)	600 - 1800	600 - 1500	800 - 1200
Substrate Bias Voltage (-V)	200 - 1000	200 - 800	400 - 700
Process Chamber Pressure (mTorr)	10 - 60	20 - 40	30 - 40
Substrate Temperature (°C)	-15 - +15	-15 - +15	-15 - +15



- 1       \* The term "source power" refers to the power that is responsible for sustaining the plasma  
2       by providing a major portion of the energy to create active etchant species in the process  
3       chamber.  
4       \*\* The term "bias power" refers to the power applied to the substrate support platen to  
5       produce a negative voltage on the substrate surface. Typically, the negative voltage is  
6       used to control high energy species bombardment and the directionality of ions toward  
7       a substrate.

8               During the development of the present method for etching carbon-containing silicon  
9       oxide films, we performed several experiments to optimize the plasma source gas  
10      composition and etch process conditions. The experiments were all performed in an Applied  
11      Materials IPS™ dielectric etch chamber, as shown in Figure 1. The results of these  
12      developmental experiments are presented in Table Two, below. The use of an IPS™  
13      dielectric etch chamber having both an outer plasma source power and an inner plasma  
14      source power provided unusually high uniformity of etch across the substrate (wafer)  
15      surface.

Table Two. Carbon-Containing Silicon Oxide Film Etching Method,  
Developmental Data

Run #	1	2	3	4	5	6	7	8
NH <sub>3</sub> (sccm)	100	100	100	70	70	70	70	70
C <sub>4</sub> F <sub>8</sub> (sccm)	25	25	25	25	18	25	28	25
Ar (sccm)	--	--	100	--	--	--	--	--
Proc. Chamber Pressure (mTorr)	60	40	40	40	40	40	40	30
Source Power (W)*	1600	1600	1600	1200	1200	1200	1200	1200
Bias Power (W)	1200	1200	1200	1000	1000	850	1000	1000
Substrate Temp. (°C)**	60	60	60	60	60	60	60	60
SiO <sub>2</sub> Etch Rate (μm/min)	3.1	2.4	2.2	2.6	2.8	2.5	2.6	2.2
SiO <sub>2</sub> : PR*** Etch Selectivity	4.1 : 1	2.0 : 1	2.9 : 1	16 : 1	6.3 : 1	25 : 1	16 : 1	13 : 1
Etch Profile	Tapered	Striation	Slight bowing	Vertical	Vertical	Vertical	Vertical	Bowing

\* This source power is a combination of the outer source power and the inner source power, where the ratio of the outer source power to the inner source power averaged about 2 : 1.

\*\* This substrate temperature value is  $\pm 20$  °C. Typically the temperature of the cathode upon which a wafer sets is about 10 °C, and the wafer temperature is about 50 °C higher, depending on the particular process operating conditions.

\*\*\* PR = Photoresist. The term "selectivity" is used to refer to the ratio of the etch rate of the SiO<sub>2</sub> to the etch rate of the photoresist.

Under the process conditions indicated above, where the chamber pressure was about 40 mTorr or less, the plasma density in the etch chamber during etching was estimated to range from about  $5 \times 10^{11}$  e<sup>-</sup>/cm<sup>3</sup> to about  $5 \times 10^{12}$  e<sup>-</sup>/cm<sup>3</sup>.

1 Etch rates for the carbon-containing silicon oxide films ranged from 2.2 to 3.1  $\mu\text{m}$   
2 per minute. (In general, an etch rate of at least 0.8  $\mu\text{m}$  per minute is considered acceptable.)  
3 Run #1 showed the highest etch rate, 3.1  $\mu\text{m}$  per minute. The atomic ratio of carbon :  
4 nitrogen in the plasma source gas in Run # 1 was 1 : 1, with a relatively high process  
5 chamber pressure (60 mTorr), source power (1600 W), and bias power (1200 W).

6 Typically, a patterned photoresist layer is used as a mask to etch a feature in an  
7 underlying layer of carbon-containing silicon oxide. The term "feature" refers to, but is not  
8 limited to, interconnects, contacts, vias, trenches, and other structures which make up the  
9 topography of the substrate surface. A UV-5 photoresist manufactured by Shipley Co.,  
10 Massachusetts, USA, was used in the development runs listed in Table Two. The  
11 photoresist layer had a thickness of about 8000 Å.

12 It is desirable that the photoresist masking layer be consumed at a much lower rate  
13 than the underlying layer which is being etched, that is, the etch selectivity for the carbon-  
14 containing silicon oxide relative to the photoresist should be high (typically, at least 5 : 1).  
15 Run #6 showed the highest silicon oxide : photoresist etch selectivity, 25 : 1. Run #6  
16 utilized an atomic ratio of 1.4 : 1 carbon : nitrogen in the plasma source gas, with a lower  
17 process chamber pressure (40 mTorr) and source power (1200 W). Run #6 also utilized the  
18 lowest bias power (850 W) out of all of the runs.

19 The best etch profile was also achieved in Run # 6. The term "etch profile" (or  
20 "feature profile") generally refers to, but is not limited to, the cross-sectional profile of an  
21 etched feature. In many instances herein, where the etched feature pattern is one of trenches  
22 etched within a substrate, the etch profile is described in terms of an angle between the  
23 trench sidewall and a horizontal line drawn along the bottom of the trench at the base of the  
24 trench. The term "vertical profile" refers to an etched trench profile where the trench  
25 sidewall is essentially perpendicular to the horizontal line drawn along the bottom of the

trench. Frequently the angle between a line drawn along the trench sidewall and the horizontal line along the bottom of the trench is about  $88^{\circ}$  and  $90^{\circ}$  (or  $90^{\circ}$  to about  $92^{\circ}$  depending on the direction from which the angle is measured). The term "undercut profile" refers to a trench sidewall profile where the width of the trench increases as the distance away from the opening at the top of the trench increases. The term "tapered profile" refers to a trench sidewall profile where the width of the trench decreases as the distance away from the opening at the top of the trench increases. A "bowed profile" is one in which the width of the trench is smaller at the top of the trench, enlarged as the trench goes deeper into the substrate, and then smaller again at the bottom of the trench.

The addition of argon to the plasma source gas in Run #3 resulted in a lowered etch rate ( $2.2 \mu\text{m}$  per minute), as well as a reduced silicon oxide : photoresist etch selectivity ( $2.9 : 1$ ). Further, the etch profile obtained in Run #3 showed a slight bowing, that is, the width of the cross-section of the feature was largest approximately midway between the opening on the substrate surface and the bottom of the feature.

Overall, Run #6 provided the best results in terms of etch rate, etch profile, and selectivity for etching the silicon oxide layer relative to the overlying photoresist layer.

As demonstrated by the results presented in Table Two, above, the method of the invention provides excellent etch rates, as well as superior selectivity for etching a carbon-containing silicon oxide film relative to an overlying photoresist layer.

Figure 2 shows the effect of changing the relative amounts of  $C_4F_8$  relative to  $NH_3$  in a plasma source gas, when the other process variables were held constant as follows: The outer source power was 800 W at 2 MHz; the inner source power was 400 W at 2 MHz; the bias power was 1000 W at 1.7 MHz; the process chamber pressure was 40 mTorr; and the substrate temperature was within the range of 60 - 100°C, most commonly at about 60 °C. Fifteen (15) Torr of helium back pressure was used against the backside of the

1 substrate wafer to assist in heat transfer. The electrostatic chuck was water-cooled.

2 The scale labeled 202 in Figure 2 shows the flow rate ranges for  $C_4F_8$  in sccm, while  
3 the scale labeled 204 in Figure 2 shows the flow rate ranges for  $NH_3$ .

4 The graphs 210 show the change in etched wall profile from vertical as a function  
5 of changes in the flow rates of  $C_4F_8$  and  $NH_3$ . The profile is shown to change from about  
6  $0^\circ$  to about  $4^\circ$ , where an increase in  $C_4F_8$  causes a decrease in profile undercut, while an  
7 increase in  $NH_3$  causes an increase in profile undercut.

8 The graphs 220 show the change in etch selectivity (etch rate ratio of carbon-  
9 containing silicon oxide : photoresist masking material) as a function of changes in the flow  
10 rates of  $C_4F_8$  and  $NH_3$ . The selectivity is shown to change from about 5.2 to about 8.7,  
11 where an increase in  $C_4F_8$  causes an increase in selectivity, while an increase in  $NH_3$  causes  
12 a decrease in selectivity.

13 The graphs 240 show the change in photoresist masking material etch rate as a  
14 function of changes in the flow rates of  $C_4F_8$  and  $NH_3$ . The etch rate is shown to vary from  
15 about 3300 Å per minute to about 4300 Å per minute, where an increase in  $C_4F_8$  causes a  
16 decrease in photoresist etch rate, while an increase in  $NH_3$  causes an increase in etch rate.

17 The graphs 260 show the change in carbon-containing silicon oxide layer etch rate  
18 as a function of changes in the flow rates of  $C_4F_8$  and  $NH_3$ . The etch rate is shown to vary  
19 from about 22,500 Å per minute to about 27,500 Å per minute, where an increase in  $C_4F_8$   
20 causes no apparent change in the carbon-containing silicon oxide layer etch rate, while an  
21 increase in  $NH_3$  causes a decrease in the etch rate. As shown in graph 260, changing the  
22 flow rate of either  $C_4F_8$  or  $NH_3$  had minimal impact on the etch rate of the carbon-containing  
23 silicon oxide film.

24 In summary, the relative amounts of  $C_xF_y$  and  $NH_3$  need to be carefully balanced in  
25 order to maintain a vertical etch profile while providing high selectivity for etching carbon-

1 containing silicon oxide relative to a photoresist masking material. Based on a series of  
2 experiments in which the carbon content of silicon oxide films was varied from 0 up to  
3 about 20%, we have also determined that films containing higher carbon concentrations have  
4 a higher etch rate when etched according to the method of the invention.

5 The above described preferred embodiments are not intended to limit the scope of  
6 the present invention, as one skilled in the art can, in view of the present disclosure expand  
7 such embodiments to correspond with the subject matter of the invention claimed below.

## CLAIMS

We claim:

- 1        1.        A method of etching a carbon-containing silicon oxide film comprising exposing  
2        said silicon oxide film to a plasma generated from a source gas comprising  $\text{NH}_3$  and  $\text{C}_x\text{F}_y$ .
- 1        2.        The method of Claim 1, wherein said carbon-containing silicon oxide film comprises  
2        less than about 30 atomic percent carbon.
- 1        3.        The method of Claim 1, wherein said carbon-containing silicon oxide film further  
2        comprises hydrogen, at a concentration of less than about 50 atomic percent hydrogen.
- 1        4.        The method of Claim 1, wherein an atomic ratio of carbon : nitrogen in said source  
2        gas is less than about 3 : 1.
- 1        5.        The method of Claim 1, wherein an atomic ratio of carbon : nitrogen in said source  
2        gas ranges from about 0.5 : 1 to about 1.4 : 1.
- 1        6.        The method of Claim 5, wherein an atomic ratio of carbon : nitrogen in said source  
2        gas ranges from about 0.6 : 1 to about 1 : 1.
- 1        7.        The method of Claim 1, wherein x ranges from about 1 to about 6, and y ranges from  
2        about 4 to about 8.

- 1        8.        The method of Claim 7, wherein  $x = 2 - 5$  and  $y = 6 - 8$ .
- 1        9.        The method of Claim 8, wherein said  $C_xF_y$  gas is selected from the group consisting  
2        of  $C_2F_6$ ,  $C_3F_8$ ,  $C_4F_6$ ,  $C_4F_8$ ,  $C_5F_8$ , and combinations thereof.
- 1        10.       The method of Claim 9, wherein said  $C_xF_y$  gas is selected from the group consisting  
2        of  $C_2F_6$  and  $C_4F_8$ .
- 1        11.       The method of Claim 1, wherein said source gas further comprises  $O_2$ , at a  
2        concentration of less than about 30 volume %.
- 1        12.       The method of Claim 1, wherein said source gas further comprises a non-reactive,  
2        diluent gas selected from the group consisting of argon, helium, xenon, krypton, and  
3        combinations thereof.
- 1        13.       The method of Claim 1, wherein said carbon-comprising silicon oxide film is etched  
2        at a rate of at least  $1.5 \mu\text{m}$  per minute.
- 1        14.       The method of Claim 1, wherein the ratio of an etch rate of said carbon-comprising  
2        silicon oxide film relative to an etch rate of an overlying photoresist layer is at least 10 : 1.
- 1        15.       The method of Claim 1, wherein a substrate bias voltage within the range of about -  
2        200 V to about - 1000 V is applied during the performance of said method.



- 1        16.    The method of Claim 1, wherein a plasma density within a substrate processing area  
2        during performance of said method is within a range from about  $5 \times 10^{11} \text{ e}^-/\text{cm}^3$  to about  $5$   
3         $\times 10^{12} \text{ e}^-/\text{cm}^3$ .
- 1        17.    The method of Claim 1, wherein a total source power applied during performance  
2        of said method ranges from about 800 W to about 2000 W.
- 1        18.    A method of etching a carbon-containing silicon oxide film comprising exposing  
2        said silicon oxide film to a plasma generated from a source gas comprising  $\text{NH}_3$  and  $\text{C}_x\text{F}_y$ ,  
3        , wherein an atomic ratio of carbon : nitrogen in said source gas is less than about 3 : 1,  
4        wherein said carbon-containing silicon oxide film resides on a substrate which is biased to  
5        within a range of about - 200 V to about - 1000 V, and wherein a plasma source power is  
6        applied using one device which is external and one device which is internal to a process  
7        chamber in which said etching is carried out.
- 1        19.    The method of Claim 18, wherein a sum of said plasma source power applied is  
2        within a range from about 800 to about 3,000 W.
- 1        20.    The method of Claim 19, wherein the ratio of plasma source power applied using  
2        said device which is external : plasma source power applied using said device which is  
3        internal is 2 : 1 or higher.

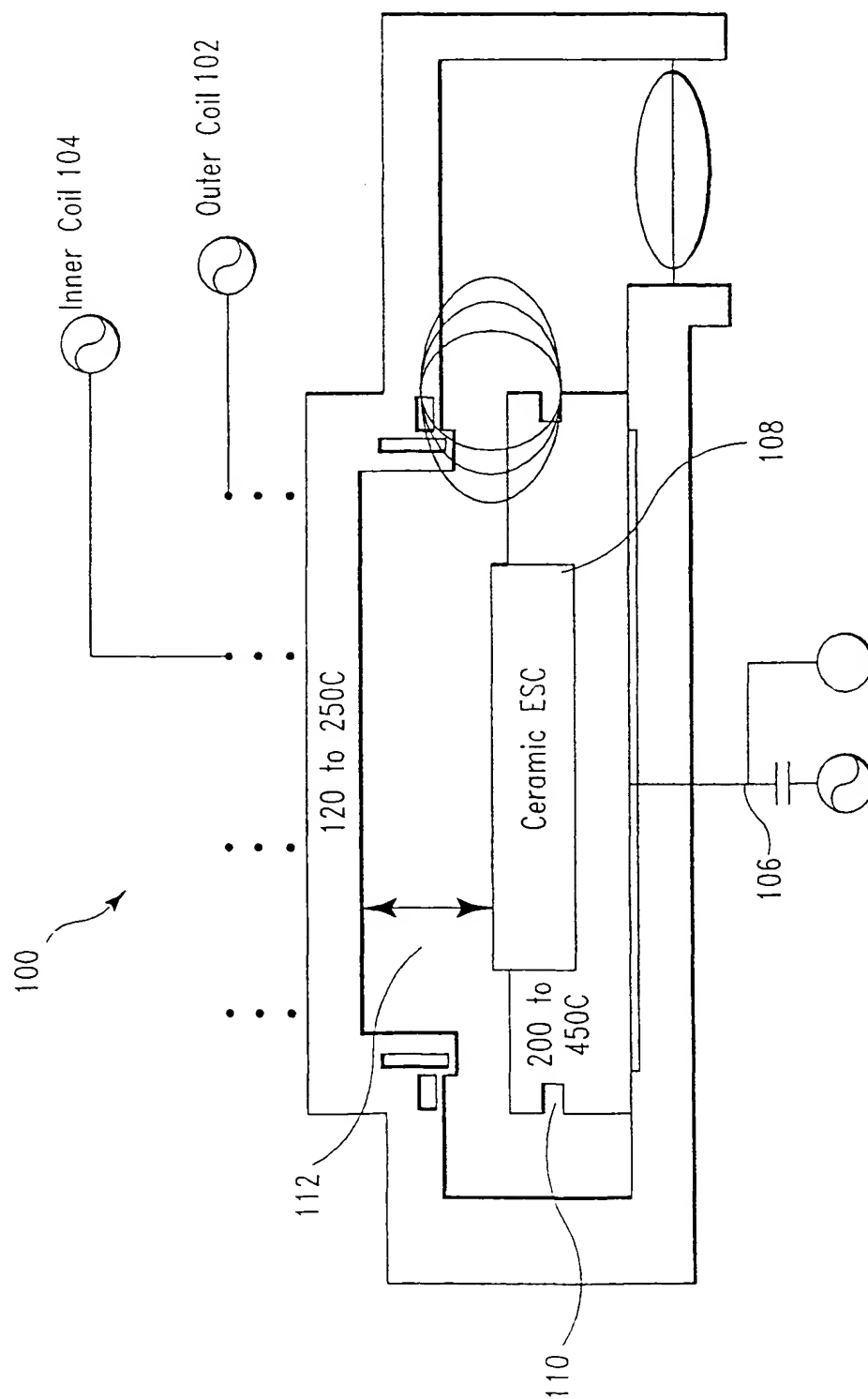


FIG. 1

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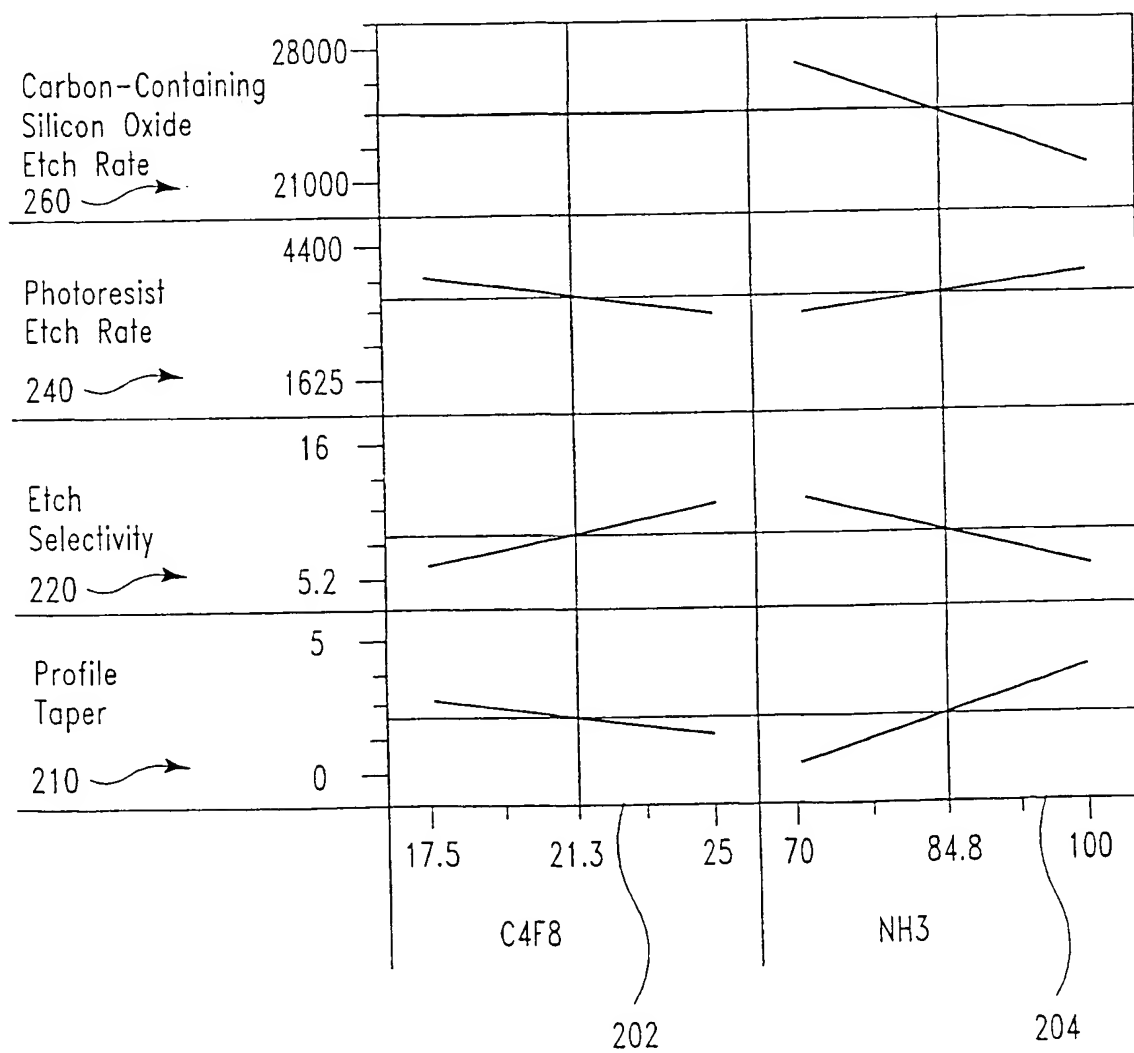


FIG. 2



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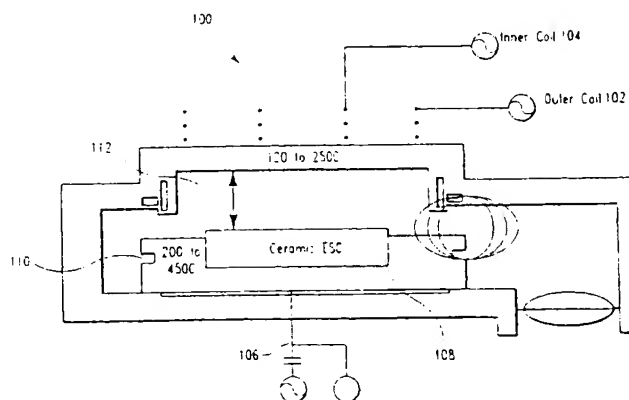
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(54) Title: **METHOD OF ETCHING CARBON-CONTAINING SILICON OXIDE FILMS**



(57) Abstract: We have discovered a method for plasma etching a carbon-containing silicon oxide film which provides excellent etch profile control, a rapid etch rate of the carbon-containing silicon oxide film, and high selectivity for etching the carbon-containing silicon oxide film preferentially to an overlying photoresist masking material. Then the method of the invention is used, a higher carbon content in the carbon-containing silicon oxide film results in a faster etch rate, at least up to a carbon content of 20 atomic percent. In particular, the carbon-containing silicon oxide film results in a faster etch rate, at least up to a carbon content of 20 atomic percent. In particular, the carbon-containing silicon oxide film is plasma etched using a plasma generated from source gas comprising  $\text{NH}_3$  and  $\text{C}_x\text{F}_y$ . It is necessary to achieve the proper balance between the relative amounts of  $\text{NH}_3$  and  $\text{C}_x\text{F}_y$  in the plasma source gas in order to provide a balance between etch by/product polymer deposition and removal on various surfaces of the substrate being etched. The  $\text{NH}_3$  gas functions to "clean up" deposited polymer on the photoresist surface, on the etched surface, and on process chamber surfaces. The atomic ratio of carbon: nitrogen in the plasma source gas typically ranges from about 0.3:1 to about 3:1. We have found that  $\text{C}_2\text{F}_6$  and  $\text{C}_3\text{F}_8$  provide excellent etch rates during etching of carbon-containing silicon oxide films

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International Application No.

PC/US 01/26314

A. CLASSIFICATION OF SUBJECT MATTER  
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According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC, IBM-TDB, CHEM ABS Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 02, 30 January 1998 (1998-01-30) -& JP 09 260350 A (SONY CORP), 3 October 1997 (1997-10-03)	1,2, 4-10,17
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X	WO 00 39846 A (LAM RES CORP) 6 July 2000 (2000-07-06)	1,2,7-12
A	page 9 -page 10; claim 2	18
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A	the whole document	18
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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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